The R390a Receiver: A Milestone in HF Communications

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The Collins-designed R390a is a familiar piece of radio equipment, as they seem to be available almost everywhere, and at a wide variety of prices. Although there are so many around, nobody seems to know much about them. I've felt for a long time that the receiver deserves more recognition than it has received, and this article shares information I have gathered over the years.

The R390a is not a rig for the timid! A person needs to be mechanically inclined and in possession of the usual radio-type electrical skills in order to be comfortable working on these 95 pound classics. However, this is exactly why I enjoy them so much -- they are high-performance radio machines! As will be discussed, they are not without shortcomings. However, with suitable modifications, an R390a in good shape can be made to be fully competitive with any receiver made.

The R390a is actually a modified R390 receiver, which was designed at Collins Radio Company around 1949 in a group headed by Lou Couillard. According to the Collins book, "The First Fifty Years", the R390 was produced from 1950 to 1954. When the military decided to incorporate the new mechanical filter into the R390, the R390a was born and production began in 1951. The following list details the production history of the R390a, which unlike the R390, was not exclusively Collins-produced.

Year	Manufacturer	Contract Number
1951	Collins Radio Co. (?)	14214-PHILA-51
1954	Motorola Inc.	363-PHILA-54
1954	Collins Radio Co.	375-PHILA-54
1955	Collins Radio Co.	08719-PHILA-55
1956	Motorola Inc.	0014-PHILA-56
1958	Motorola Inc.	14385-PHILA-58
1960	Stewart-Warner	20139-PC-60-AI-SI
1960	Electronic Assistance Corp.	22137-PC-60
1961	Capehart	21582-PC-61
1962	Amelco	35064-PC-62
1963	Imperial/Teledyne	37856-PC-63
1965 (?)	Stewart-Warner	DA-36-039SC-81547
1967	Clavier Corp.	DAAGQ5-67-C-0016
1967	Electronic Assistance Corp.	DAAB05-67-C-0155
		FR-36-039-N-6-00-00189(E)

Collins R390a

(All R390a's produced by Imperial/ Teledyne have Imperial on the front nameplate, but the internal parts are manufactured by Teledyne. Also, I have never seen one from the first order, and don't know who produced it.)

I'm not sure how many of us are aware of the lengthy 16 year production history of R390a's or how dependant the services were on it during this time. The total production figures are not known, but I've seen serial numbers on most of these groups as high as 4800. Assuming this amount for each production order (and that the serial numbers are sequential), then there must have been at least 67,000 R390a's manufactured. The cost per unit probably varied by an enormous amount, as they were made through quite a period of time. Once, all high value surplus equipment was required to be tagged with it's acquisition value. At a Denver surplus store in the late 1970's, I saw a 1958 Motorola rig with an acquisition value of $2,895. I would guess that the later ones ran much more than this, because this figure was in pre-inflation dollars!

Support Equipment

There was also an interesting collection of support equipment which was available for use with the R390a, and this list is by no means complete. The CV-591/URR SSB converter is a well-known unit, which uses the 455 kc I.F. output as an input to a product detector and audio section. I've seen diagrams showing the CV-591 used with RTTY terminal units. In addition to the DV-591, there were two or three other SSB converters, including full diversity units.

Also available is the CV-116/URR FSK converter. This 100 pound gem is designed to combine two R390a audio outputs in full diversity reception and produce RTTY loop signals. The CV-116 used motor-driven automatic frequency correction circuitry, and these motors are

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what is responsible for its great weight.

Perhaps the most interesting, and most mysterious, was the CV-1982/URR radio terminal. Very little is known about this equipment, and only a few pieces have made it onto the surplus market. The CV-1982 was a full diversity SSB radio terminal with automatic frequency correction, derived via a tube-type phase-locked loop. The PLL used unusual nuvistors with plate caps. This terminal was designed to be used with the TSC-26 SSB Space Terminal, which was made up of two component parts, a transmit shelter and a receive shelter. Any further information regarding this equipment would be greatly appreciated.

Electrical Design

The R390a is a classic Collins Radio Company design. In general, it consists of a main frame and six subchassis. (It is unusual to find one with all the modules produced by the contractor on the front panel label!) The receiver tunes 500 cps to 32 Mcs in 32 bands, and is triple conversion below 8 Mcs and dual conversation above 8 Mcs. The first and second conversion oscillators are crystal controlled, the third L.O. is a Collins-design PTO. All the tuning is linear, accomplished by the movement of powdered-iron slugs in variable-pitch coils matched to core permeability, which was designed by Ted Hunter at Collins. Dial resolution is 100 cps, but with a good PTO, calibration can be maintained within 50 cps.

The receiver has a balanced 125 ohm antenna input, and a 50 ohm unbalanced input. The balanced input is designed for a doublet antenna, or if one side is grounded, a long-wire may be used. The connector type is UG-573/U, available from Fair Radio Sales.

The unbalanced input takes a type "C" connector, and is designed for a very short feedline run, as is typical of a vehicular installation using an 8 foot whip. Poor results will occur using this input with much of anything else. Both antenna inputs are routed to a built-in antenna relay, which grounds the antenna when the receiver is off, in standby, during calibration, or when the break-in mode is used during CW transmission. A neon lamp and a 220K resistor are across the unbalanced input, to drain static buildup on the mobile whip. The lamp fires and shorts the resistor when the static potential exceeds 80 to 90 volts. (Cheap insurance!) Antenna transformers are used in tuned circuits to match antenna characteristics to the RF amplifier, and these six transformers are tuned and selected via front-panel megacycle change and kilocycle change knobs. These high-Q transformers also provide considerable selectivity, a nice touch in these days of wideband front-ends. Between the antenna transformers and the RF grid circuit is a front-panel antenna trimmer, and an L-C network which is connected to the AGC line. During very strong-signal reception, the network adds to the negative grid bias and causes grid current to flow in the RF amp, reducing the possibility of distortion products occurring. The stock RF amplifier is a low-noise 6DC6, which has a cathode structure designed specifically for reduction of innermodulation distortion. Also at the front end is a 100 kc calibrator, which is derived from a 200 kc over-controlled crystal oscillator and a 100 kc multivibrator. This arrangement provides for long-term stability of about 1 cps. The plate circuit of the RF amplifier is a band-switched group of six high-Q transformers, tuned by megacycle change and kilocycle change controls.

All three of the stock mixers in the R390a are AGC-controlled 6C4 triodes. This is remarkable for it's day, as most HF mixers of the period were fairly noisy pentagrid types. The 6C4 was designed for use as a VHF oscillator or a class-C RF amplifier. In mixer service, it has an equivalent noise resistance of 7.2 K,

which was very quiet for the mid-fifties. Collins designers were also after low distortion in the mixer outputs. The injection oscillators are coupled to the cathodes via high-Q, shielded tuned circuits to remove noise sidebands from the injection voltage and provide proper L.O. termination. The result is a quiet, clean, mixer with high dynamic range.

If the receiver is tuned between 500 cps and 8 Mcs, signals from the RF plate circuits are switched into the first mixer to produce the first variable I.F. of 17.5 to 25 Mcs. Note that this is up-conversion, used to reduce images. The first L.O. is an oven-controlled Colpritts crystal oscillator, in the same oven that holds the calibrator crystal. The oven temperature is maintained between 73 and 78 degrees, and is of the plug-in variety.

When tuned between 8 and 32 Mcs, the RF signals are switched around the first mixer, and fed directly to the second mixer. If tuned below 8 Mcs, the second mixer grid receives the first variable I.F. The AGC is fed to a high-Q, triple-tuned transformer network, which is tuned by the kilocycle change knob. Just these transformers alone would have been all the I.F. selectivity simpler receivers would have gotten, yet they are ahead of the special mechanical filters in the last I.F.!

The second crystal oscillator deserves special mention. It is built on its own subchassis, and the crystal bank is thermally insulated. If the rear-panel oven switch is on, the crystal bank (and the VFO subchassis) becomes heated and thermostatically controlled. The megacycle change control drives two decks of a 32-position bandswitch. One deck selects one of the 15 crystals for the grid circuit of the 6AK5W oscillator and the other deck selects the plate circuit, which is tuned either to the fundamental, second or third harmonic of the selected crystal, depending on the band in use. Ceramic trimmers in the plate circuits assure proper alignment.

The third mixer takes the second variable I.F. of 2 to 3 Mcs and the VFO and the VFO injection voltages to produce the final 455 kc I.F. If the receiver input frequency increases, the second I.F. decreases, and the VFO injection frequency also decreases. The rate of change between the second I.F. and the VFO is such that the plate of the third mixer is always tuned to 455 kcs. The third mixer output transformer has a center tapped secondary winding, so that the output is balanced and the second-order harmonics are cancelled. I bet you thought balanced mixers were new, huh?

The VFO is a Collins-designed PTO, although only a few were actually made in Cedar Rapids. It is mechanically similar to the PTO's used in the Amateur Product Division, but it has been sealed and ovenized for use on the R390a. It consists of an outer cover, fiberglass insulation, a heater and thermostat, and an inner cover which surrounds the PTO components. These PTO's are individually calibrated and temperature-compensated. I have one which actually has a pressure fitting on the rear cover, similar to pressurized microwave feedline connectors. These are used to keep moisture out of the insides, and normally carry 1-3 lbs. of dry air. In common with other Collins PTO's sacks of silica gel are taped to the frame stand-offs inside the inner case. The purpose of these sacks is to absorb moisture, and turn pink when they are full. They may be baked in a stove to restore them to a blue color, and re-used. (The subject of Collins PTO repair and calibration will be the subject of a future article here in ER.)

The VFO circuit is an electron-coupled Hartley, where the screen grid of the pentode acts as the plate of an equivalent triode oscillator. Its effect is to reduce the oscillator loading. In the early fifties, this was high-tech stuff! The VFO tunes from 3.455 to 2.455 Mc., and by

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careful use of the end-point adjustment, a good one will produce dial accuracy of 50 cycles.The VFO output circuitry is designed to hold the injection voltage constant over the 1 Mc. tuning range.

If the 100-cycle or 1-Kc. bandwidth positions are selected, the 455 Kc. I.F. voltage is fed into a single-crystal bandpass filter. This filter, while adequate, is nowhere near as narrow as a good crystal lattice filter. Fortunately, a razor-sharp audio filter is provided and used together, the CW op has a very dangerous weapon here!

Signal voltage, no matter which bandwidth is selected, goes next to the first I.F. amp., a conventional AGC-controlled 6BA6. This stage has only about 12 dB gain, just enough to overcome the filter loss, but not enough to cause a spurious response in the filter input transducers. In the case of 100-cycle or 1-Kc bandwidths, the 2 Kc. filter is in series with the crystal bandpass filter to limit overall skirt response. In performance, the mil-spec Collins' filters are quite unlike any others. I have a full set of filters in my A-4 and have had S-Line equipment. I don't know how to describe the difference, except that the R390a selectivity must be heard to be appreciated. The input and output filter terminals are on opposite ends of the filter, and are very well shielded and isolated. I sure get spoiled on SSB using the 2 Kc filter, because unless another station gets right on top of a QSO, adjacent traffic usually is just not heard. They are FB on SWL'ing the broadcaster, too. Ceramic trimmers are included to properly resonate the input and output transducers. A little-known fact is that some 413 receivers from order number 22137-PC-60 used ceramic filters instead of Collins' mechanical filters. These were ordered changed to mechanical filters when they failed. The mechanical filter trimmers were installed during production, but not used!

Following the filters are two conventional AGC-controlled 6BA6 455 Kc. I.F. amplifiers, each with a gain of about 20 dB and a non-AGC controlled 4th I.F. amplifier. An I.F. cathode follower, picked off at the grid of the 4th I.F. amplifier, feeds the AGC circuitry and the I.F. output jack. The AGC system is a fair performer on AM, but on other modes it has insufficient range to assure undistorted reception when using the BFO and the attack time is too long, which makes the audio sound like it pumps. (Part two of this article will take care of this problem.) The AGC has three time constants, .015, .3, and 5 seconds. The 4th I.F. amplifier (6AK6) is transformer-coupled to the plate detector, a 5814A.

The BFO is unusual in that it is a mini-PTO in a sealed can. It is coupled to the front panel control thru a backlash-free flexible coupling. The BFO circuit is an electron-coupled Hartley oscillator. No oven is provided, but it does not drift, either.

If the front-panel limiter switch is on, audio from the plate detector is fed to a two-stage dual-diode peak limiter. It limits on positive and negative peaks and is one of the more effective limiters I've used. It is not equivalent to a good blanker, however. I am working on a solid-state blanker for the R390a and will present it in ER in a future article.

The audio is then routed through a 5814A triode preamp, a 5814A cathode follower, to contacts on the break-in relay, and back to the audio response switch. In the sharp position, an 800 cps bandpass filter is selected. This is an excellent filter, with little loss and a 100 cycle bandwidth and really works well digging weak CW sigs out from the background.

Audio is split across the front-panel audio gain pots and is routed into two separate audio channels. Both have 5814A triode preamps feeding single-

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ended 6AK6 P.A's. The local audio output is unbalanced 600 ohms, and the line audio output is balanced 600 ohms. The VU line level meter is really calibrated in VU, where "0" VU is 1 milliwatt across 600 ohms. I use the line level meter mainly for zero beating, where the last one or two cycles in calibration may easily be seen.

The power supply is hum-free and may be connected to run off of either 120 or 220 VAC mains. The 26Z5W (hard to find) rectifiers feed a stiff choke-input filter, producing about 240 volts of B+. The audio section is fed from a 2-12 Henry swinging choke and a 4 Henry choke. The RF and IF B+ line is fed from the swinging choke and a 6 Henry choke with 45 uf caps in a Pi-filter configuration. An OA2 feeds regulated 150 volts to the 1st and 2nd crystal oscillator screens. The filaments of the VFO and BFO are fed from a ballast tube, an RT510/3TF7. The job of this tube is to regulate emission temperature by controlling filament current, which regulates the oscillator. If you don't have a good supply of these tubes, either find some real fast or use KDØHG's modification which was presented in ER #9.•

Editor's Note: Next month Ray begins Part Two with the mechanical design of the R390a.

Mystery Collins Prototype from page 11

Florida. Ed is also a former Collins engineer. No luck there either; but I did have a delightful conversation with Ed. Probably more on this in a later issue. He thought that maybe Gene Senti (another Collins engineer) would know.

Gene gave me a phone number and address in California but Mr. McKay was no longer there. My last call was to Bill Stewart, K6HV. Although Bill left Collins in the early '50s I though he might know Bill McKay. Bill says that he did not but will try to track him down for me. We'll have the full story in a future issue; maybe next month. •

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fall of 1952, his unit got PRC-6's to replace the BC-611's; the PRC-6 gave very little trouble.

Brand new ideas which don't work perfectly are a lot better than much of what you see in military radios. Overall, the BC-611 is brilliant work; when the Smithsonian Institution someday displays this area of our technological history, the '611 should be out in front with the ART-13 and command sets as one of the outstanding designs of all time. •

Editor's Comments from page 1

Walt Hutchens, KJ4KV, in his "Electric Radio in Uniform" articles has covered military gear in a way that makes that area of collecting interesting to everyone. Walt is highly respected by both military collectors and classic radio collectors. I think his articles will be used as a reference by collectors for the rest of time.

Fred, Bill and Walt I want you to know that ER would not be the same without you and I appreciate the contribution you've made to the magazine over the past two years. And there are dozens of other contributors that have left their mark on the magazine. I won't try to list them all - for fear of leaving someone out - but I want you all to know how much I've appreciated your efforts; thanks and God Bless.

Last month I published a list of KW-1 owners. I credited the list to information I had received from the owners. Since then I've learned that most of the information was compiled originally by Ed Bolton, WA3PUN. He started the list in 1985 and plans to add to it and update it as he receives new information. So if any of you have new information for the list, Ed would appreciate your forwarding it on to him. Ed's address is 4212 Jonestown Rd., Harrisburg, PA 17109. (717) 545-5030. Here's a new one for your list Ed; Mike Moody, WA5MCL, has acquired SN 60. He found it in a shed somewhere in Florida.

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PART TWO

Since last month's issue of ER, a few more facts have come to light regarding R390a production history. Sam, W8KBF, wrote and mentioned that he has an R391 receiver from the first order, which I listed as being produced in 1951. The R391 is an autotune version of the R390, which was produced for only a few years. I got my original information from an Army book listing modification work orders to the R390a, and I was in error assuming that the 1951 contract number referred to the R390a. Production began in 1954. Also, I ran across yet another production contract. The following data, which came from an I.F. sub-chassis, may be added to the previous list:

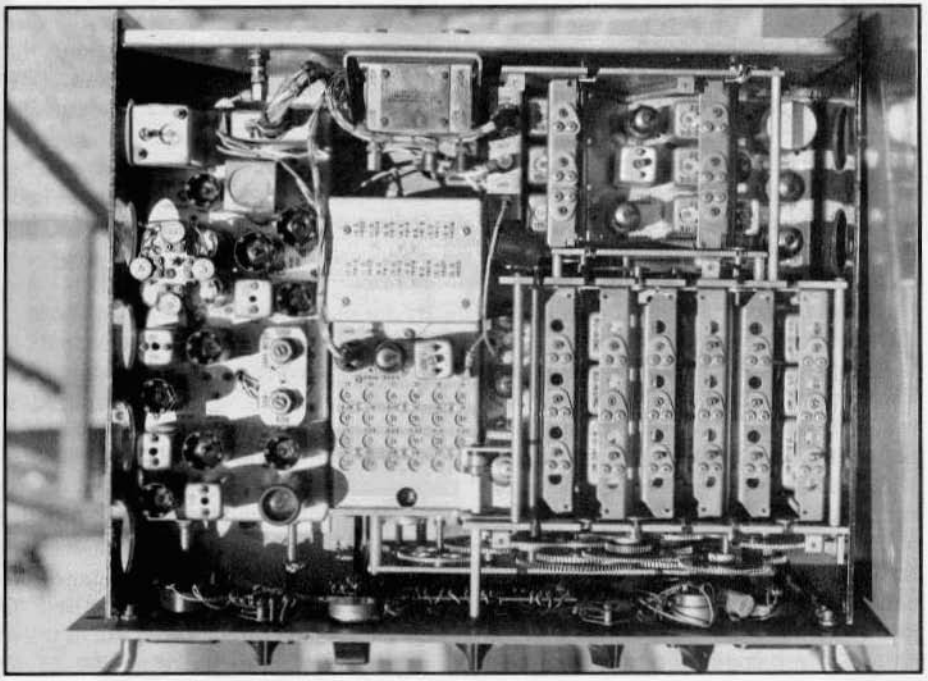
1959, Stewart-Warner, 42428-PC-59-Al-51

Michael, KK7F, wrote to mention his 1967 R390a. It has a very high serial number, 6278. Probably I have under-estimated the total R390a production figures, as I have recently received an I.F. subchassis from this same 1967 order with a serial number over 10,000. He also mentioned that he uses a CV-157 SSB converter which weighs over 100 pounds and has 44 tubes. This unit uses an accurate electromechanical phase-locked loop that does very well eliminating drift and distortion.

I've had a very pleasant conversation with Mr. Ed Andrade, WØDAN, who was a Collins design engineer in those exciting years of the early 1950's. He went on to design the 5-Line receiver, and is personally responsible for the up-conversion schemes used today in imported transceivers and commercial gear. Mr. Andrade's contribution to the R390 and '390a was in the engineering of the diversity combiners. This turned out to be a system of two six-foot racks with two R390a's, power supplies and the combiner, which received AVC levels and "voted" on the receiver with the strongest audio, which was then routed to the operator.

He had some interesting comments about the development of the R390. Lou Couillard - who passed away recently - was the project leader. He was aided by mechanical engineers Bob Griswold and Winston Williams. Ed Houge was the engineer in charge of the R390 electrical design. Mr. Houge designed the 513 receiver, and the R390 evolved directly from the work done on that series. I asked Mr. Andrade if Art Collins had any specific direction in the development of the R390, and he replied:

"I don't think he was all that interested in it, really. He was off thinking about ham gear at that time. I think, well it was a little later, he got very involved with getting single sideband going, in fact he had the signal corps just mad as hell at him because they'd come out with a contract, and we were already working on it, for a mobile HF system. He stopped it right in the middle of it, and decided it was going to go single sideband. They were about ready to sue him, but he got the idea across. He started working with General LeMay and Butch Griswold. That was the time that he really got the kWS-1 and the 75A-4 going, which were the radios on those flights



Collins R390a, top view

they took around the world in the early days of sideband and made a believer out of all of them. So sideband really got going. Of course he didn't invent it, it had been around for a long time, and again a lot of things came together at the right time. Mechanical filters and some very stable VFOs for the time and that made it possible to make a useable system that didn't take sixteen relay racks of equipment."

I mentioned I had heard that the Amateur Products Division didn't really make much money for Art Collins, and Mr. Andrade replied:

"No, but there were plenty of spinoffs that came from it. That was the real benefit of it and he knew that. Ham stuff always got a lot of attention, personal attention. He couldn't stand a three-day weekend. There were always some of us on call, somewhere. He'd get bored and start inventing."

Mechanical Description

The mechanic's portion of the R390a is in a word, complex. Please do yourself a favor by not attempting any major work on the tuning system without the technical manual. This is not meant to imply that service in this area is beyond the abilities of the average person, because it is not. You will just not be able to get it back together in operating condition!

The RF gear train assembly is made up of about 32 gears, 16 cams, two 10-turn stops, a differential, an overtravel coupler, and an intermittent gear, plus couplings, clamps, spacers, etc. Watching all of this in motion is similar to watching a steam locomotive, but I haven't yet found a boiler in the R390a!

The tuning system is typical quality Collins mechanical engineering, and is decended from Ted Hunter's (WØNTI) wartime PTO design work in the AN/ART-13, TDO and TDH Navy transmitters. It provides for continuous, linear

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tuning from 500 Kcs to 32 Mcs in 32 1 Mc. bands, except for the first band which is 500 Kc. to 1 Mc. It is resettable from a cold start to within 200 cycles! To accomplish this feat, not only must the proper coils and transformers be selected at the right time, but the coil slugs must move up and down at the proper rate. As an example of the precision required to tune just the 500 Kc. to 1 Mc. range, the slugs in T201 (R.F. grid circuit) and Z201 (R.F. plate circuit) move .8 inch, their entire motion. At the same time, the slugs in Z213 (1st mixer plate circuit) move .05 inch to cover this range. This is accurate, repeatable, and controllable with a single knob, yet the coil slugs were not hand-selected during production!

The gears which drive the camshafts, the ten-turn stops, and the pinion gears on the differential are split, spring-loaded gears to eliminate backlash in the tuning system. The cams which furnish motion to the slug racks have rollers at each end, and identical cams at each end of the cam shaft. Both the kilocycle change and megacycle change knobs are connected to a common differential.

The digital readout can be set between 0 and 500 Kcs., and the VFO tunes over this range, but there are no front end coils for the L.F. spectrum. The stock R390a won't receive in this range.

Rotation of the megacycle change knob is limited by a 10-turn mechanical stop and a detent. Each stop position selects the first two digital counter positions, corresponding to thousands of kilocycles. Each rotation picks one of 32 2nd crystal oscillator switch positions, and one of 7 RF bandswitch positions. The RF bandswitches and the first mixer bypass switches are operated through an intermittent gear (it only moves its mating gear sometimes) and an overtravel coupler. Through the differential, all the slug racks are brought into proper position, except for .5 to 1 Mc, 1 to 2 Mc, and 2nd V.I.F. racks. Rotation of the kilocycle change knob is continuous, but limited by another 10-turn stop. Through this stop, the knob is coupled to the PTO, to the 2nd variable I.F. slug racks, and also to the 500 Kc. to 32 Mcs. antenna and RF circuit slug racks. As it is connected to the differential, the kilocycle change knob controls movement of all of the 1st variable I.F. slugs. The 1st V.I.F. slugs are pre-positioned at a starting point selected by the megacycle change knob. The kilocycle change knob is directly coupled to the last three digits of the counter, and it reads out in kilocycles and hundredths of kilocycles, with some overlap at each end. At this point, I hope I don't have to mention that this is a mechanical digital display!

Via a clutch, the zero adjustment control on the front panel disengages the gear train from the PTO, and the PTO may be set over about a 15 Kc. range to accurately calibrate the receiver.

SERVICE HINTS

When removing and replacing the VFO or the R.F. sub-chassis, the Oldham coupler which connects the PTO to the turns counter must be removed. On replacement, loosen the triangular mounting plate at the rear of the PTO for a little extra working clearance. It also helps to get a few extra anti-backlash springs from Fair Radio Sales. A GC Electronics spring hook tool saves deforming them.

The front panel must be removed for restoration work, or for removal of the crystal oscillator or R.F. sub-chassis. This procedure only takes a few minutes once learned, but there are a few tricks to make it easier. Most all of the shaft clamps and setscrews on the front panel controls are sealed with lacquer. A little acetone usually loosens it up, and a #8 Bristo wrench fits all of the clamp screws in the receiver. (Bristo wrenches are available from GC Electronics, or from the Bristo Division of American Chain and Cable, Bristol Road, Waterbury CT.

06720) Once the Mc., Kc., and antenna trimmer knobs are off, use some #600 grit wet sandpaper to smooth the shafts out. This is done to avoid scoring the panel bearings, and it makes panel removal easier. The location of the clamps which hold the front panel wiring harness varies. Having them free makes front panel removal much easier. On replacement, be sure not to pinch the wiring harness between the front panel and the mainframe. Set the mainframe on a short piece of 1X2 lumber to allow clearance for the front panel to drop down. When re-installing the front panel, be sure the 3 panel bearings are clean. Loosen them with a spanner wrench, reinstall the panel, tighten up the 8 screws on each side and then lubricate and tighten the panel bearings. This makes the tuning shafts 'ride' free, and avoids some of the binding common in un-restored receivers.

When removing the R.F. sub-chassis, first loosen the right side mainframe panel for additional clearance. A Phillips head screwdriver with a 6 inch shank will be needed to reach the captive head screws at the rear of the R.F. and crystal oscillator sub-chassis. Also be very careful and lift the chassis straight up, as the shielding fingerstock underneath it is easily damaged. Replacement fingerstock may be ordered from Fair Radio Sales, or in lengths from Instrument Specialties Co., Inc. in Delaware Water Gap, PA, 717-424-6213. Remove the crystal oscillator and the R.F. subchassis as a single unit.

Proper cleaning and lubrication is vital to smooth operation and avoidance of the dread 'R390 wrist'. I was fortunate to have access to an ultrasonic cleaning machine where I once worked, and I disassembled the gear train and cleaned each part. It may not be necessary to go to this detail, but bearings, journals, and sliding surfaces need to be clean to work properly. Flush cleaning is OK if compressed air is available to blow out all the old gunk, but do not use a cleaner which gets into the bearing metal, such as trichlor. I use a watch rinse solution made by the L&R Manufacturing Company in Kearney, N.J. 07032. Your local watchmaker may also be able to get you some. Using a GC Electronics syringe, put a little rinse on at a time, work the bearing and journal, and then blow it out. As for an air supply, I found an old but operable Sears compressor at a garage sale for $25. The rinse solution is also good for cleaning chassis parts if used sparingly, but do not use it on, or allow it to come into contact with electrical parts.

I lubricate all the R390a bearings and camshaft rollers with a special synthetic oil which is impregnated with Teflon called "Trick Super Oil", and is available from PBL, Box 749, Chama, New Mexico, 87520. Some hobby shops may also have it. This stuff is specially made for bearing-journal surfaces, has superior lubrication properties, and stays where you put it. For the sliding surfaces, I use DuPont "Super Lube", which is Teflon in another synthetic compound. I do not lubricate any gear teeth except for the intermittent gear, which gets Super Lube. Also put some Super Lube on the megacycle change detent. When lubricating, check the cam rollers for damage. If they are deformed they will do more sliding than rolling. Also, if performing lubrication with the R.F. sub-chassis installed, be careful when cleaning around Z213, as the rear section of the bandswitch is directly below the chassis cutout. I don't use Lubriplate, as it works good for a short while, then dries out.

At the limiter, V507, use only a 5814W and not a 12AU7, as it produces much less distortion and harder limiting action.

Get a supply of IREC black tube shields from Fair Radio Sales. These are modern shields, designed for maximum thermal transfer, and really work fine.

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They increase tube life 20-30%, and save on scorched fingers, too!

The VFO end point adjustment procedure in the technical manual is very hard to follow. I use an alternate method which is given below:

1. Remove the VFO sub-chassis and then remove the cover plug over the end-point adjustment at the front. Replace the VFO.

2. Set the mainframe on its wooden block, set to 5 000 Mc., and remove the front panel. Replace the Kc. change knob. Check that one of the 3 holes in the riveted locking plate lines up with the end point adjustment screw when the dial is set to 5 +000. If it does not line up, loosen its clamp and align it. (A flashlight with a bright, thin beam will help here.) Be sure to re-load the gear by one tooth, and then tighten the clamp screw. Set the receiver on its right side panel, being careful not to damage wiring or the front panel, as they will still be loose. Get a cup of coffee and allow the receiver to warm up at least 3 hours.

3. Re-tune to 5 000, loosen the clamp holding the VFO shaft coupler, and zero beat with WWV at 100 cycle I.F. bandwidth, using the free end of the VFO shaft. Tighten the VFO shaft coupler. Zero beat the BFO against WWV. Perform the calibrator zero adjustment.

4. Tune back to 5 +000. Loosen the VFO shaft coupler. Turn on the calibrator and zero beat the VFO against the calibrator. Tighten the VFO shaft coupler.

5. Re-tune to 5 000, and again zero beat with WWV, but use the end point adjustment this time. You will need a thin, straight blade screwdriver with a 6 inch shank to reach the adjusting screw.

6. Repeat steps 4-5 until the desired dial accuracy is obtained, or until you can't stand it any more.

7. Reassemble the receiver and enjoy.

PERFORMANCE DATA

The following tests were performed with military test equipment (calibration was checked against recently calibrated labquality equipment) on a stock 1956 Motorola '390a. All the tubes were checked, and a complete mechanical and electrical alignment was performed. The test frequency was 14.100 Mcs, and each test was performed three times to verify the results. These numbers are nothing less than amazing for a receiver designed forty years ago.

1. Total harmonic distortion: 6.2% (4 Kc bandwidth, 1000 uV RF input, modulated 30% at 400 cps. Each audio channel was terminated in 600 ohms.)

2. BFO distortion: 9.6% (same conditions as above except 100uV RF input)

3. Noise Floor: .14uV (-127 dBm) at 2 Kc bandwidth, and .013uV (-147 dBm) at 100 cps. bandwidth. (Noise floor is defined by the signal level required to produce 3 dB gain over the no-signal noise level.)

4. 10 dB S/N ratio: .44 uV (-117 dbm) at 2 Kc bandwidth.

5. AM sensitivity: 1uV.

6. Blocking dynamic range: 72.1 dB (With 2 Kc. bandwidth and 20 Kc. signal separation, a test frequency signal level of 2.5uV., 1 dB gain reduction was reached at -54.9 dBm, or 400uV.)

7. 2-tone, 3rd-order dynamic range (spurious-free dynamic range): 52.7 dB (at 10 Kc. signal separation, 2 Kc I.F. bandwidth. IMD level was -49 dBm. This is worst-case and would be higher if measured at the ARRL lab standard of 20 Kc. signal spacing)

8. Power supply ripple: .012%

Stability

(All stability measurements were made with the ovens switch "off", and the receiver out of its case)

Short-term stability: From a cold start (measured with the BFO zero-beat with WWV at 10 Mc) to +1 hour, beat-note drift was +210 cps after 20 minutes, then

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back down to +140 cps after an hour.

From cold start to +20 minutes, the calibration oscillator, 1st crystal oscillator, and 2nd crystal oscillator drifted no more than +2 cycles! The cold-start drift in the BFO was no more than -50 cycles, therefore most of the short-term drift is due to thermal instability in the VFO.

Long-term stability: After a one-hour warm-up, a frequency counter attached to the VFO revealed no more than +260 cycles of drift. After a three hour period, drift was no more than +75 cycles. After warming up for 2 days, the counter showed no more than +1 cycle drift in the VFO in three hours and the BFO stayed zero beat with WWV at 10 Mc. within +-5 cycles for three hours.

At this level of stability, its hard to tell what is drifting, my 35 year-old receiver or my solid-state counter!

Next month Part Three

CV-157 from page 14

Now what is the use of such a device for AM phone as we exercise it today? I don't know exactly. I believe the FCC frowns on pilot carriers for T-R synchronization, but there is a VOA station around 19,260 khz doing just that. They transmit a 20 dB reduced pilot carrier with English on USB and a foreign language on LSB. I have occasionally found a leaky sidebander down on 20 meters (maybe running an old HT-37 with the phasing out of adjustment) and have locked on to him. He sounds perfectly natural - a pleasure to listen to.

Historically, (and I am not sure of this) the CV-157 was designed and prototyped by Hoffman Labs. I have an 8 1/2 by 11 glossy of their prototype with a serial # of 1 on the front ID plate. Back in those days, Hoffman was in competition with Collins and others for military contracts. I believe they got some, but in the area of high powered Navy HF transmitters, HF vertical antennas and VLF receivers. They did design and prototype a receiver similar to the R-390 and SP-600 with 2 Mhz bands, an extravagant noise limiter, and a slide-rule dial similar to the 51J, but I have never heard nor seen one in real life.

I think that about wraps it up concerning the CV-157. The rest, I'll leave to the imagination of those who already possess such a unit, or to those who may in the future possess one after reading this introductory article. I wish you all luck.

Letters from page 21

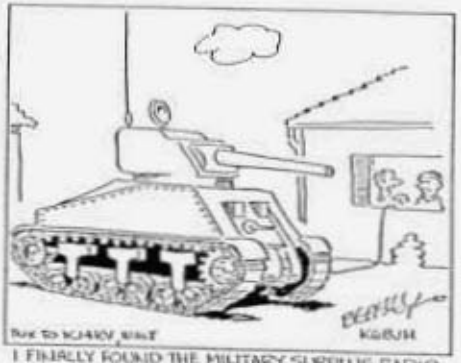
while we are at dock here in Pearl Harbor as RF emmissions may trigger an explosion. I hope to have my ham station operational upon departure 5/18/91. Give my regards to K6HQI and the rest of the gang on 20 meters.

I will send you pictures of the vessel I am on and it's radio room. By the way the station is equiped for AM operation and has a linear amplifier.

Marc Guitard, WA4IRE

Editor's Comment:

I think there's a good many of us that would like to be in Marc's shoes. Didn't we all want to be radio operators at one time or another? Good luck Marc.



I FINALLY FOUND THE MILITARY SURPLUS RADIO I ALWAYS WANTED, BUT I HAD TO BUY THE ENTIRE MOUNT TO GET IT

The R390a Receiver: A Milestone in HF Communications

by Ray W. Osterwald, NØDMS
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PART THREE

The "Competition-Grade" R390a

While the debate over modifications to vintage equipment rages on, one fact we can't change is that we are faced with operating in the modern radio environment. I hold in high regard the craftsmen among us who restore vintage radio gear and accept it for what it is. Future generations will appreciate what they do. I use my equipment for regular operations, and have found that some older circuitry must be modified simply to do its job in this era of high-power finals, directional antennas, multi-national pile-ups, etc. Where I draw my personal line is a modification which requires a non-electrical change: holes, new switches, or similar damage. I document every change I make so that another person with electronics skills may remove them if so desired. The parts situation with the R390a is unique, in that replacement modules are both plentiful and relatively inexpensive, so that a person may have both modified and stock sub-chassis, and enjoy the best of both.

This part of the R390a series gives a listing of all of the relevant U.S. military authorized modifications I have, plus simple, un-authorized modifications made by me to the AGC circuitry, and to the RF and IF sub-chassis to get over 120 dB of blocking dynamic range, and a sensitivity which approaches the galactic noise limit around -150 dBm. I agree with KDØHG's arguments in ER #22, and I just don't buy into the reasoning that a noisy receiver is acceptable.

The modifications to be described may be performed on the I.F. and R.F. sub-chassis. If you are not comfortable removing the front panel or the R. F. sub-chassis, then the I.F. mods alone may be made, which results in very substantial improvements. I recommend doing the entire job, and learning to remove all the component subchassis. It is not really very hard, and maintenance is much easier with everything apart. When de-soldering, do the job right by using lots of solder wick and patience, as a failure deep inside the R.F. sub-chassis is frustrating! Also, don't use too much heat around the Teflon tie points on the R.F. sub-chassis, as they are easily damaged.

AGC Modification

This procedure greatly reduces distortion when receiving SSB and CW transmissions, and shortens the attack time enough that the AGC no longer pumps. If no other mods are made, this one is well worth the hour it takes to do it.

1. Orient the I.F. sub-chassis up-side down, with the switch shaft to the right.

2. Referring to figure #1 and the sub-chassis, remove R546, 180K, which runs from V509 pin #2 to the stand-off post to the right of the tube socket. Replace it with a 1N914 or 1N4148 diode, with the cathode towards pin #1 of V509.

3. Remove R545, 100K, which runs from V509 pin #2 to a ground lug underneath the stand-off post to the right of V509 tube socket.

4. Replace R547, 220K, with 10K. R547 runs from pin #2 of V506 to a binding post to the upper right of the V509 socket. Also on this post is a 2.7 Meg resistor and a white wire with green and brown tracers.

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Collins R390a from page 22

5. C547 significantly affects AGC attack time. Most of the original paper caps are leaky. Change C547 (.1 500V paper to .005 uF disk ceramic 500 Volt. This cap runs from V508, pin #2, to the ground lug directly beneath it on the chassis divider wall, where two other caps are grounded.

6.Change the BFO coupling capacitor, C535, from 12 uuF to 49 uuF silver mica, 400 VDC (47 uuf is the closest standard value) 49 uuf is an optimum value which reduces BFO distortion to less than 5%. C535 runs from V505 pin #5, to V506, pin #7.

7.Perform the BFO neutralization procedure as given in the manual. This isimportant in order to realize the least possible distortion.Ifonlyperforming the AGC modifications, be sure to re-align 2503 forproper AGC action.I.F.

Amplifier Modifications

The I.F. mods consist of replacing some of the 6BA6 I.F. amplifiers with 6JH6 types, and removing the swamping resistors originally across the I.F. transformer windings. The 6JH6 is a quiet, high performance AGC-controlled I.F. amplifier with a semi-remote cutoff characteristic from the early 1960's. It was designed for use in gain-controlled picture I.F. stages in the last of the tube color TV receivers. As an amplifier, it has an equivalent noise resistance of 1094 ohms, about 3.5 times quieter than the stock 6BA6. Its inter-electrode capacitances are very similar, as is the plate resistance. Plate curves may be found in some late Sylvania tube manuals. Pin outs are different, as the cathode and suppressor grid pins are reversed. This is usually not a problem, as they are frequently tied together. I had no trouble finding lots of these tubes, either on sale or $3.50 new.

The first I.F. amplifier bias is not changed, as increased gain in this stage would likely introduce intermodulation distortion at the mechanical filter input transducers. I use a 6JH6 here as it is slightly quieter, with the gain equivalent to a 6BA6. The 4th I.F. amp is not changed. It is a 6AK6, and while it is fairly noisy, there is so much gain ahead of it that its noise is completely masked by signal. I have found that Philco 6AK6's have higher Gm than the others.

Amplifier Modification Procedure

1. Replace V501 and V502 with 6JH6.
2. Replace V503 with 6JH6.
3. Orient I.F. chassis as before, and replace C543 (.1 uF, paper) with .1 uF disk ceramic, 500 Volt. (pin #7 to ground lug.)
4. Remove the covers from T501, T502, and T503. Locate resistors R511 and R512 in T501, R553 and R554 in T502, and R522 in T503. These resistors were designed to lower the tuned Q of the transformers and broaden their response for multichannel reception. Removed, the I.F. channel can be made much sharper. Avoid soldering on these transformers. Clip one end of a resistor free, and slip a piece of shrink tube over the free end. This will allow for re-attachment if ever necessary to return to the original configuration.

5.Change R541 (AGC I.F. amp cathode bias resistor) to 1000 ohms. It runs between V508, pin #7, and ground. (This change may not be necessary on all of the I.F. sub-chassis, as later ones seem to behave differently. Do it only if the AGC voltage, as measured with a VTVM at the rear panel, is much less than -2 volts DC with the antenna disconnected, or if alignment of the AGC I.F. 2503 has insufficient range.)

6.Realign T501, T502, T503 and 2503 for maximum gain, using a high-impedance D.C. voltmeter across the rear panel AGC-NOR terminals. (The procedure in some of the technical manuals is for a stagger tuned I.F. response, which will no longer be needed.) 2503 may be adjusted by ear for the best AGC "balance": the receiver should not have so much AGC gain that circuit and background noise reduce weak signal levels. Also,

T503 may be tweaked to produce minimum distortion when receiving strong CW and SSB signals. It may be set by ear, or with a distortion meter if available. The optimum position may not be the one which gives the greatest gain, but should be within a half-turn of the aligned position.

7. Perform the I.F. gain adjustment.

Filter Alignment Procedures

The crystal filter alignment procedure in the manual is ambiguous. An alternate procedure is given below:

1. With the power off, remove the cover from the crystal filter. Remove the crystal and clean the pins and socket with residue-free contact cleaner. Re-install the cover, and warm up the receiver. Tune in any calibrator marker, and reduce the RF gain to produce a fairly weak signal. Connect a VTVM across the rear panel AGC terminals, set the AGC to "fast".

2. With the bandwidth switch in the 100 cycle position, slowly tune through the calibrator signal. Note the filter response on the VTVM. If there are two peaks, peak the receiver up on the lesser of the two. Adjust the trimmer, C520 (top of can) until the peak is minimum. Double-check this step by "rocking" the receiver across the calibrator signal. Peak up again on the calibrator signal.

3. By carefully tuning across the calibrator signal and watching the VTVM, adjust C520 until the response falls off evenly on both sides of the peak (a symmetrical bandpass).

4. Turn the bandwidth control to 1 Kc. Check that the response peak occurs at the same frequency as it did in the 100 cps position. If not, re-peak the receiver in the 100 cps position, and without changing frequency, change back to 1 Kc bandwidth, adjust L503 (top of can) for a peak. Repeat steps 3 and 4 until no further improvement may be made.

5. Change to 100 cps bandwidth, and re-peak the receiver. Change to 2 Kc bandwidth and without changing frequency, peak the mechanical filter input and output trimmers.

6. Step 5 may be repeated for the other three mechanical filters.

When completed, these steps will get the R390a as selective as possible.

The results of the I.F. modifications are as follows:

A. Minimum Discernable Signal: -130 dBm at 2 Kc. bandwidth, or a 3.6 dB improvement.

B. 10 dB S/N ratio: .2 uV

C. Single-tone blocking dynamic range: 105.2 dB. (33.1 dB improvement)

D. Two-tone blocking dynamic range: 82.8 dB. (30.1 dB improvement) These are significant improvements, but we are not done yet!

R.F. Sub-chassis Modifications

These changes involve modifications to the RF amplifier bias resistors so that ultra-low-noise frame-grid tubes may be used, and a different mixer is installed which is 8 times quieter than the stock 6C4.

The frame grid was invented around 1958 and was a structure which approached the "ideal grid" configuration of electrical characteristics without physical dimensions. As such, the grid to cathode spacing is much smaller and is controlled by "centerless ground" rigid support rods and cross-braces. Hence, the plate to screen current ratios are much higher and higher Gm is possible. Microphonics are reduced. The grid wires are made very much finer, which eliminated some space-charge problems.

The bias changes allow the use of the 6GU5, 6GM6, or the 6JK6 as the R.F. amplifier. These tubes were described by KDØHG in ER #22. I ran sensitivity and dynamic range tests on all of them, and found that the quiet one is the 6GU5, but the one which produced the greatest sensitivity was a 6JK6. The dynamic range is within 1/2 dB on 2 of them, with the 6GM6 being 1.5 dB better. The 6GM6 is a semi-remote cutoff type and does a

continued next page

little better job matching the R390a AGC characteristic. The 6GU5 is a heptode design, and due to its internal connections, the R.F. gain control doesn't have much effect on cathode bias. This is not really a problem, as the AGC still has sufficient range. My suggestion would be to use what you can get, but look for 6JK6.

The mixer type I use is the 6HA5 triode. This is another high performance tube designed at the end of the hollow state era, and was intended for use as a VHF R.F. amplifier in TV tuners. Internally shielded, it has a VHF noise figure of about 4 dB, an equivalent noise resistance of 888 ohms. Among triode mixers, only Nuvistors and some ceramic types have lower ENR and noise figures. It was also designed to minimize intermodulation distortion. Its inter-electrode specifications are much different than the 6C4, so I was skeptical at first of having any success with it. Also, no plate curves were available. I breadboarded the 6HA5 using the same circuit values and voltages as in the R390a and found it to be much more linear than the 6C4, and it runs cooler!. This tube is also very easy to find, and cheap. Try to get the RCA variety which is just a 6HA5 and not the 6HA5/6HM5 combination produced by others.

Bias Resistor Modifications

1.Refer to figure #2 and orient the R.F. sub-chassis with the gear train to the left.

2. Remove R233 (470K) and replace it with 3.3 Meg. 1/2 Watt. This resistor is connected between V2Ol, pin#1, and the Teflon post to the left of the socket. Be careful of this standoff, as too much heat will damage it.

3. Remove R20l (270K) and replace it with 3.3 Meg. 1/2 Watt. This resistor is connected to two other Teflon standoffs to the left of the V20l tube socket, and is connected at each post to white/orange wires.

4. Add a 3.3 Meg. 1/2 Watt resistor (R233a) from the junction of the new R233 and C255 at the Teflon post to a ground lug on the left sidewall.

5. Add a 1N914 or a 1N4148 diode across the new R201, with the cathode toward the AGC line (away from V201 socket) at a Teflon feed-thru.

Mixer Modifications

1st mixer V202 is not changed. To do so would require making up new mini-coax cables which run all over the sub-chassis. Other work necessary to change the mixer would likely degrade the shielding integrity of this section.

2nd Mixer

Refer to figure #2.

1. Remove all components from the V203 tube socket. Do a neat job, using plenty of solder wick. Completely remove the heater by-pass cap, C302, between pin #4 and a ground lug.

2. Remove the tube socket and rotate it 180 degrees. This is not as bad as it sounds, as everything is easy to get at.

3. Install the 27 ohm grid bias resistor (R214) to pin #1.

4. Install 2.2K (R215) and .005 uF (C287) to the cathode, pin #2. This is the 2nd L.O. injection.

5. Ground pin 3 (heater return) to the center sleeve.

6. Solder a new wire to L203 (10 uH heater choke) long enough to reach around to pin #4. Insulate the lead with shrink tubing and solder to pin #4.

7. Solder C302 (heater by-pass cap) between pin #4 and the tube socket center sleeve with very short leads.

8. Solder the lead from the Teflon standoff to the plate at pin #5.

9. Solder pin #6 (internal shield) to the center sleeve.

10. Do not connect pin #7.

3rd Mixer

1. Refer to figure #2.

2. Remove the plate lead from V204, pin #1.

3. Remove the 27 Ohm grid resistor (R230) and solder it to pin #1.

4. Solder an insulated jumper from pin

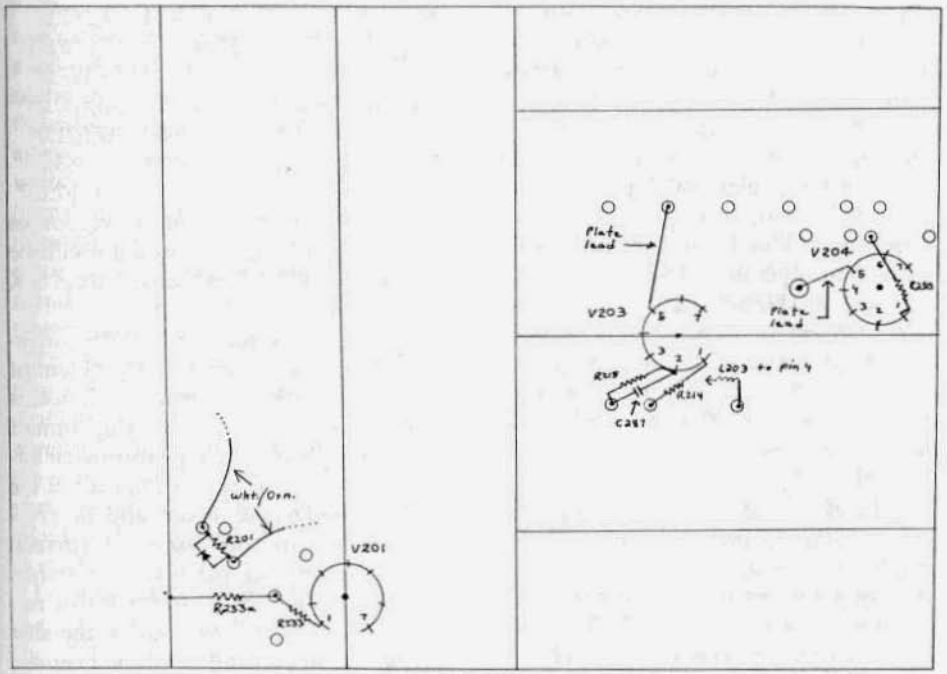

FIGURE 2

#2 to pin #7.

5. Solder the lead removed in step #2 to the plate at pin #5. The wire needs to be shortened a little bit.

6. Solder a wire from pin #6 (internal shield) to the center sleeve and ground lug.

The performance results are as follows:

A. The minimum discernable signal is now less than -150 dBm. I say "less than" because the measurement is now limited by my test equipment leakage!

B. 10 dB S/N ratio: .022 uV.

C. AM sensitivity: .1 uV at 4 Kc I.F. bandwidth.

D. Single-tone blocking dynamic range: 123.5 dB.

E. Two-tone spurious-free dynamic range: 101 dB at 20 Kc. signal spacing, and 85 dB at 10 Kc. spacing. Dynamic range measurements are also limited by equipment leakage, so the numbers are probably conservative.

This level of performance in a tube receiver takes a little getting used to! Weak signals jump out of the quiet background, as there is no receiver-produced digital QRM. Strong signals sound clean and undistorted. Intrestingly, a solid-state rig needs balanced diode ring or FET mixers to equal it, usually at the expense of sensitivity.

Government Service Notes

The following are portions of NAVSEA R-390a/URR bulletin 0967- LP-000-0010 which details Navy modifications and hints.

1. Tests at 55 discrete frequencies, using the unbalanced antenna input and long runs of coax resulted in a 42 dB degradation of received signal strength. The recommended fix was to use an adapter, UG-970/U, and re-connect the antenna to the balanced input. This adapter grounds one side of the balanced input.

2. When the zero-adjust knob is turned too far clockwise, the clutch disk may break loose from the shaft. A procedure is given to have a machine shop repair

continued next page

R390a from previous page

the damage. If this part is not available from Fair Radio Sales, an SASE to the author will bring a copy of the procedure.

3. When in calibrate or standby, the antenna input terminal is grounded. When using antenna patch panels, every thing else also becomes grounded, which apparently caused confusion among the Navy radio operators. Their solution was to use the AN/SRA-12 antenna switch to disconnect the R390a.

4. Type 328 panel lamps have a service life of 1000 hours. They may be replaced with type 381 with a life of 20K to 30K hours, but are not shock resistant. Use them only while ashore!

5. Field Change #6 outlined replacing the vacuum rectifiers with silicon diodes. This was done to a large number of the receivers, but resulted in the plate voltage on 6AK6's V603 and V604 (audio amps) increasing 20 to 35 VDC. This increased plate to cathode voltage to between 200 and 215 volts, causing internal short circuits and damage to the cathode bias resistors. The fix is to install a power supply B+ dropping resistor. If you need the dropping resistor procedure, please SASE. I do not have the diode rectifier change #6.

6. In installations where the receiver is not easily removable, a procedure was given to mount the carrier level adjustment pot on the front panel, as this was a monthly interval adjustment.

7. For use by the Naval Security Groups, a list of internally generated spurious responses was prepared. In the following list, frequencies marked with an asterisk are responses resulting from parasitic oscillation in the RF amp. The others are generated in the VFO via harmonic mixing. Note that only 28.7.55 Mcs falls inside our bands!

910.13	5,637.8	10,318.7	13,712.51
1,500.24	6,303.1	10,763.9	13,864.34
1,635.0*	6,999.76	10,945.96	16,122.0*
2,368.0*	7,841.07	11,068.84	17,381.0*
2,727.75	8,376.0*	11,564.04	18,626.0*
3,227.2	8,591.2	11,746.02	19,397.0*
4,000.6	9,340.95	12,364.01	25,680.08*
4,970.13	9,568.3	12,546.0	27,621.0*
5,357.0*	10,091.19	12,627.0*	28,755.0*
			30,392.00*

The cure for these spurious responses is to change R-210 (1st crystal oscillator screen) and R702 (VFO screen) from 56K 1/2 Watt to 220K 1/2 Watt.

8. A radio operator on the USS Forrestal reported a solution to a problem of continuing lack of sensitivity. It seems that vibration on board his ship caused the tuning slugs to change from their adjusted position. This, in turn, caused the tank circuits of the mixers and 1st crystal oscillator to draw excessive current. The cathode and plate resistors then overheat, and in some cases, fail. The recommended fix was to re-align the slug racks, and put a drop of Glyptol cement on the adjustment threads. It was noted that all of these resistors should probably have their wattage value increased, but that since the R390a was being replaced with the R-1051/URR it would be too costly. While the average ham shack does not vibrate like the Forrestal does, a little Glyptol on the slug threads after alignment is still a good idea!

Acknowledgements:

Mr. Norm Litsche, KA2TYT, (Air Navigation Industries, Inc., P.O. Box 191, Canandaigua, NY 14424) provided the Navy technical bulletins and much information about R390a production history and the support equipment. He is an excellent source of information and supply for these receivers. At this writing, he has available government rebuilt PTOs in the original sealed packing, all of the component sub-chassis, plus complete receivers. His pricing is very reasonable.•